CORRELATES OF BURROW LOCATION IN BEECHEY GROUND SQUIRRELS

Donald H. Owings[1] and Mark Borchert[1]

Abstract.— Partial correlation analysis indicates that Beechey ground squirrels show a strong preference for digging burrows under and around large objects, may show a weaker tendency to locate their burrows under the cover of tree canopies, and avoid digging burrows in areas with both tree-canopy and ground cover (stones, logs). These relationships hold for large but not small burrow systems. The need for unobstructed visual surveillance and an autumn food supply are proposed to be determinants of these preferences.

Beechey ground squirrels (*Spermophilus beecheyi*) appear to show preferences for areas with certain characteristics for the location of their burrows. At least three factors have been suggested to affect the choice of burrow sites: (1) burrows are often constructed under large objects such as stones or logs (Linsdale 1946: 9); (2) good drainage is said to be important, which is best provided by sloping terrain (Tomich 1962); (3) burrows often seem to be concentrated under the cover of tree canopies (Fitch 1948). One purpose of the research reported here was to quantitatively assess the relationship between burrow location and these three independent variables—ground cover (stones, logs), slope of terrain, and tree canopy cover. In addition, we felt that the effect of ground and tree cover might interact, or at least be additive, in areas in which these factors physically overlapped. We therefore added a fourth independent variable (common cover) to the analysis which consisted of a measure of the amount of area having ground and tree cover in common.

It is probably true, though, that burrow systems of different sizes may differ in their relationship with these variables. Small systems, for instance, may be established by young squirrels who have moved into less than optimal habitat during dispersal, or by adults for refuge from predators when feeding in the open (Fitch 1948; Carl 1971). A second purpose of this research was to divide the burrow systems into size categories for separate analysis.

Study Area

This study was done in the Department of Zoology Experimental Wildlife Area on the campus of the University of California at Davis (elevation about 15.85 m; 38° 32′: N, 121° 47′: W). The study plot was located in the 82-m wide original bed of Putah Creek which is now permanently dry. This area contained numerous trees (principally black walnut, *Juglans hindsi*, and valley oak, *Quercus lobata*), grasses (principally ripgut brome, *Bromus rigidus*, with some Italian ryegrass, *Lolium multiflorum*, and wild oats, *Avena fatua*), and thistle (*Centaurea solstitialis* and *Silybum marianum*), as well as logs, and included most of both sloping sides of this cross-section of the bed. A substantial population of squirrels inhabited this area: 44 were trapped and marked in 0.60 ha in the spring of 1973. This area was being mapped in preparation for behavioral studies.

Methods

Our procedure was to lay out a grid of 9.14 x 9.14 m squares and to map on graph paper the location of all burrow entrances, the location and size (to scale) of ground cover, and the outer limits of tree canopies for each of 50 of these squares. We derived measures of ground cover area, tree canopy area, common area, and number of burrow entrances from these maps. Slope was measured over uniform sections of the area; new measures were taken wherever significant changes in slope occurred.

We assumed that size of burrow system was positively correlated with numbers of entrances. We used a portable blower (Steco Model DS-5) and nontoxic smoke bombs (Superior 0.5 min) to assess the number of entrances in a system by blowing smoke into one en-

[1]Department of Psychology, University of California, Davis, California 95616.

trance and designating as connected to that entrance all burrows emitting smoke.

Results and Discussion

In order to minimize the problem of correlated independent variables, we calculated partial correlation coefficients. This statistic provides a measure of the correlation of burrows with each independent variable, while holding the effects of the remaining independent variables constant. The results of this analysis can be found in Table 1. The first (uppermost) row includes burrow systems of all sizes and suggests that Beechey ground squirrels (1) show a strong preference for digging burrows under and around large objects, (2) may show a weaker tendency to locate their burrows under the cover of tree canopies, but (3) avoid digging burrows in areas with both tree-canopy and ground cover.

In order to test the hypothesis that the larger systems were the ones most consistently associated with our independent variables, we successively separated increasing sizes of small systems and analyzed them separately from the larger systems. The results of these analyses are presented in the remaining rows of Table 1. It is clear that there is little effect upon the relationship between burrows and ground cover of deleting from the analysis burrow systems with 1 to 4 entrances. However, deletion of 5-entrance systems from the large-system analysis caused a large drop in the correlation coefficient. Addition of 5-entrance systems to the small-system analysis results in the first significant correlation with ground cover. We conclude that small burrow systems tend not to be associated with ground cover, whereas larger systems (5 or more entrances) do.

The negative correlation with common cover and the positive correlation with tree cover followed the same pattern when system size was manipulated. As a result, we conclude that it is principally the larger systems which tend not to be associated with areas having overlapping ground and tree cover, but which are located under or near tree cover.

Our behavioral observations indicate that squirrel concentration was correlated with burrow concentration, and G. L. Hunt (unpubl. data) has quantitatively documented this in another location ($r = 0.80 - 0.85$ between numbers of squirrels and burrow entrances). We assume then that our data indicate microhabitat selection by these ground squirrels.

We feel that the strongest determinant of this propensity to live in the vicinity of ground cover is the visibility it provides. Hunt (unpubl. data) has gathered considerable support for the hypothesis that Beechey ground squirrels in a much more open area tend to concentrate in locations in which their ground level view (probably of approaching predators) is least obstructed by locating themselves

TABLE 1 Partial correlation coefficients between the numbers of burrow entrances from burrow system of various sizes (dependent variable) and the independent variables (1) slope, (2) ground cover, (3) tree cover, and (4) common cover. Size of burrow system is expressed as the number of entrances to the system.

Burrow system sizes included in analysis	Number of entrances included in analysis	Partial correlation coefficients of entrances with Slope	Ground cover	Tree cover	Common cover
1-39	261	-0.067	0.620*	0.231	-0.382*
1	23	0.010	0.012	0.325*	-0.220
2-39	238	-0.067	0.613*	0.187	-0.354*
1-2	39	0.106	-0.116	0.051	0.069
3-39	222	-0.089	0.636*	0.225	-0.398*
1-3	54	-0.009	-0.089	0.054	0.013
4-39	207	-0.064	0.629*	0.216	-0.383*
1-4	74	0.109	0.053	0.029	0.043
5-39	187	-0.100	0.591*	0.211	-0.378*
1-5	92	0.079	0.407*	0.134	-0.250*
6-39	169	-0.089	0.484*	0.164	-0.271*
1-6	107	0.025	0.369*	0.122	-0.238*
7-39	154	-0.071	0.486*	0.164	-0.266*
1-7	127	0.027	0.316*	0.246*	-0.233
8-39	134	-0.075	0.503*	0.104	-0.265*

*With $df = 48$ an r of $\pm$ 0.236 is significantly different from 0.0 at $p = 0.05$.

appropriately on slopes and in areas of low vegetation. Linsdale (1946: 63) has argued that the disappearance of squirrels from the Hastings Reservation at the termination of regular grazing was caused by the visual obstruction of the taller grass. In our area the grass regularly reaches heights of a meter, but the squirrels appear to compensate for this by using the numerous promontories (ground cover) for visual surveillance when disturbances occur, as well as when simply lying, sitting, or grooming. A similar factor could account for the avoidance of common cover, since a considerable amount of the ground cover beneath tree canopies was made up of small, highly branched logs, sticks, and twigs. Some of the ground cover was beneath canopies which almost reached or did reach ground level. Such cover is often neither readily mounted nor useful for visual surveillance since the canopy would often obstruct the view. The same factor might also explain our failure to find a relationship with slope. It is possible that the preferences of squirrels in flat land for embankments is related more to enhanced visibility than to drainage (Hunt, unpubl. data).

Visibility seems an unlikely determinant of the preference for tree-canopy cover. We concur with Fitch's (1948) suggestion that this preference is related to the food available in the trees, i.e., acorns in his case, and acorns and walnuts in ours. These are the primary food sources in the fall when the grass, grass seeds, and forbs eaten in the spring are no longer available (Schitoskey 1973).

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